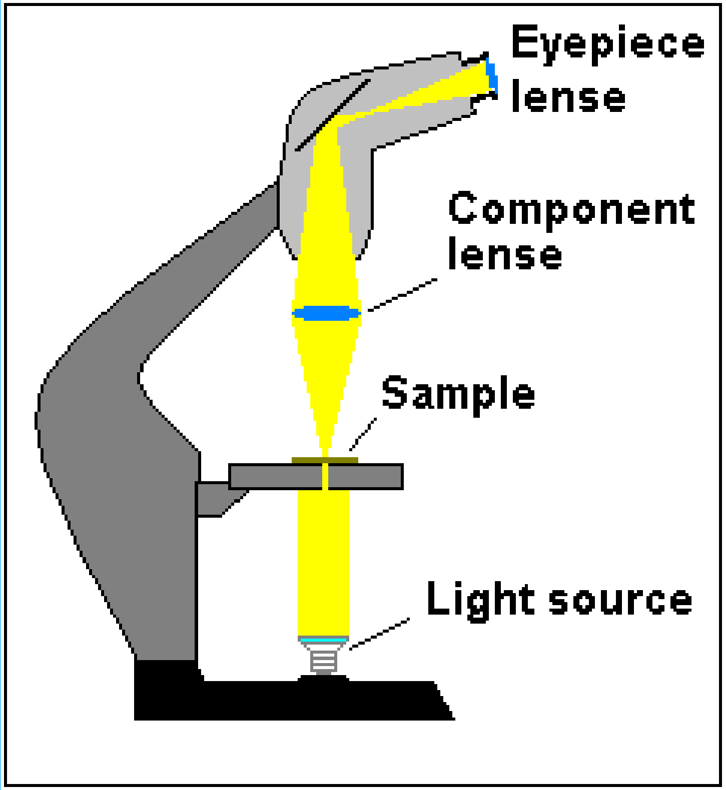
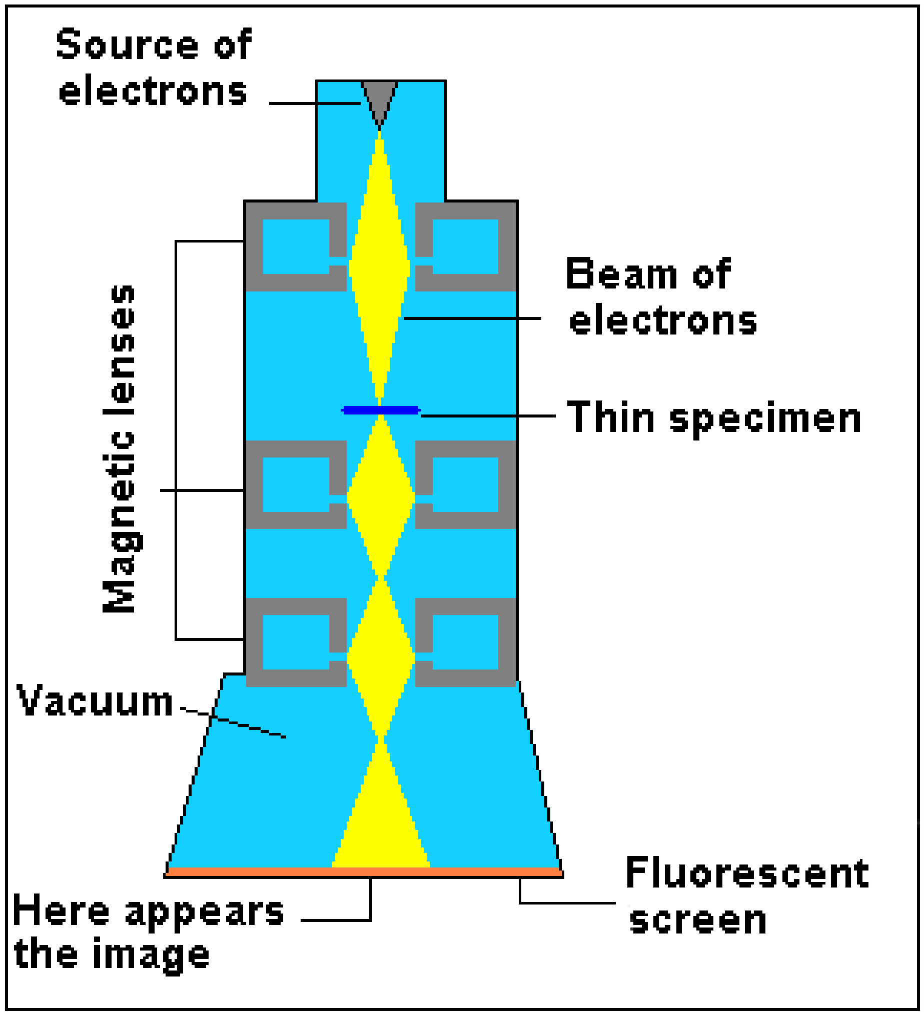
# Diffraction in the Transmission Electron Microscope

# TEM- What is it?




Optical microscope




Transmission electron microscope

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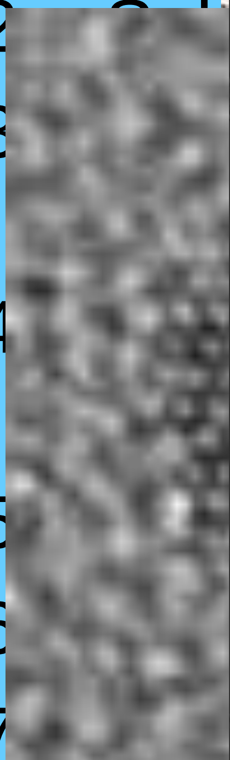
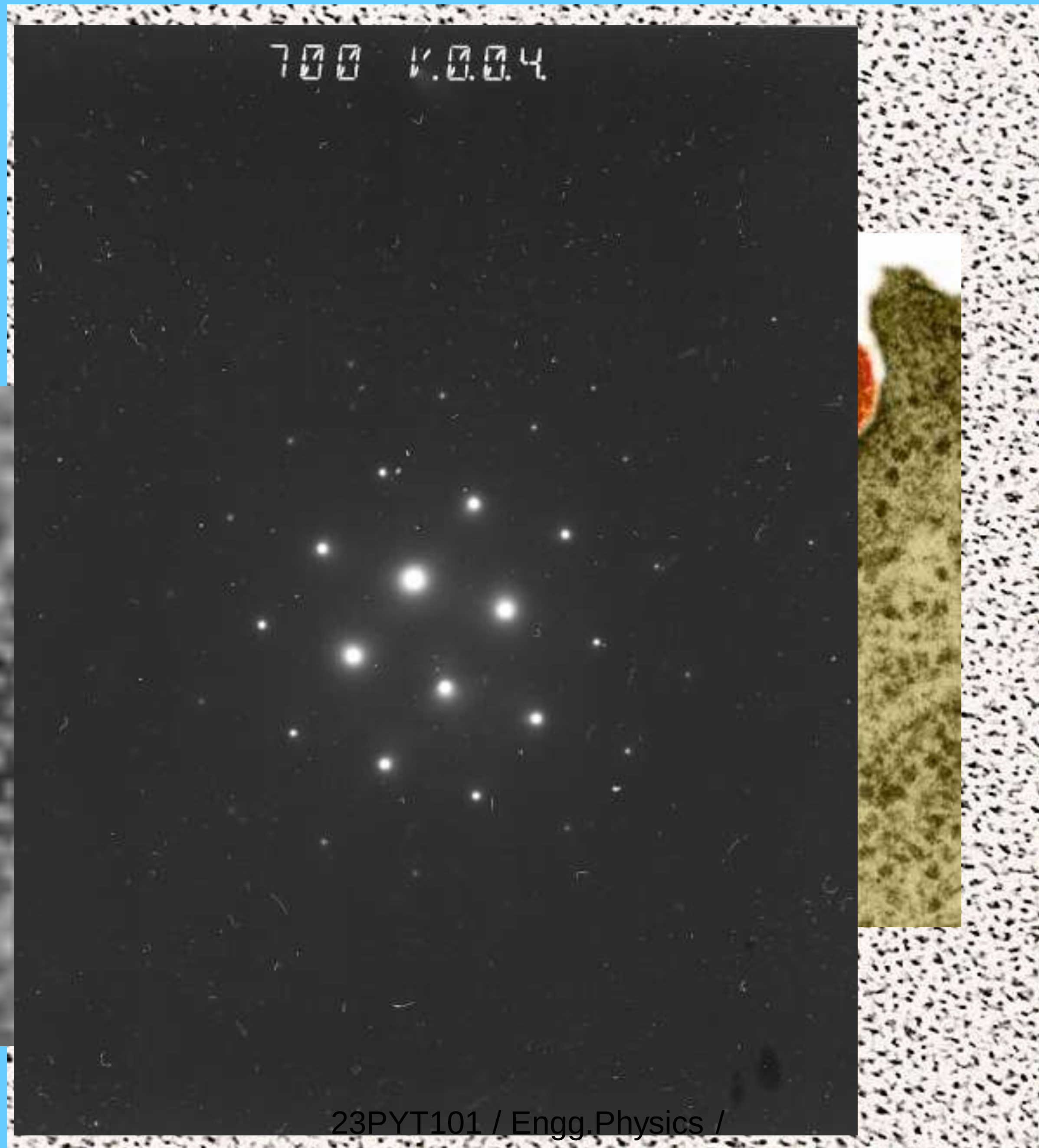




# Disadvantages of TEM

1. Sample size
2. Preparation
3. Instrument issues
4. Operation
5. Interpretation

# Wavelength of electrons

## Wavelength – magnification

$q*U = \frac{1}{2} mv^2$, $\lambda = h/ (m * v)$

where:

$\lambda$ = wavelength

$h$ = Planck's constant ($6.6 \times 10^{-27}$)

$m$ = mass of the electron ($9.1 \times 10^{-28}$)

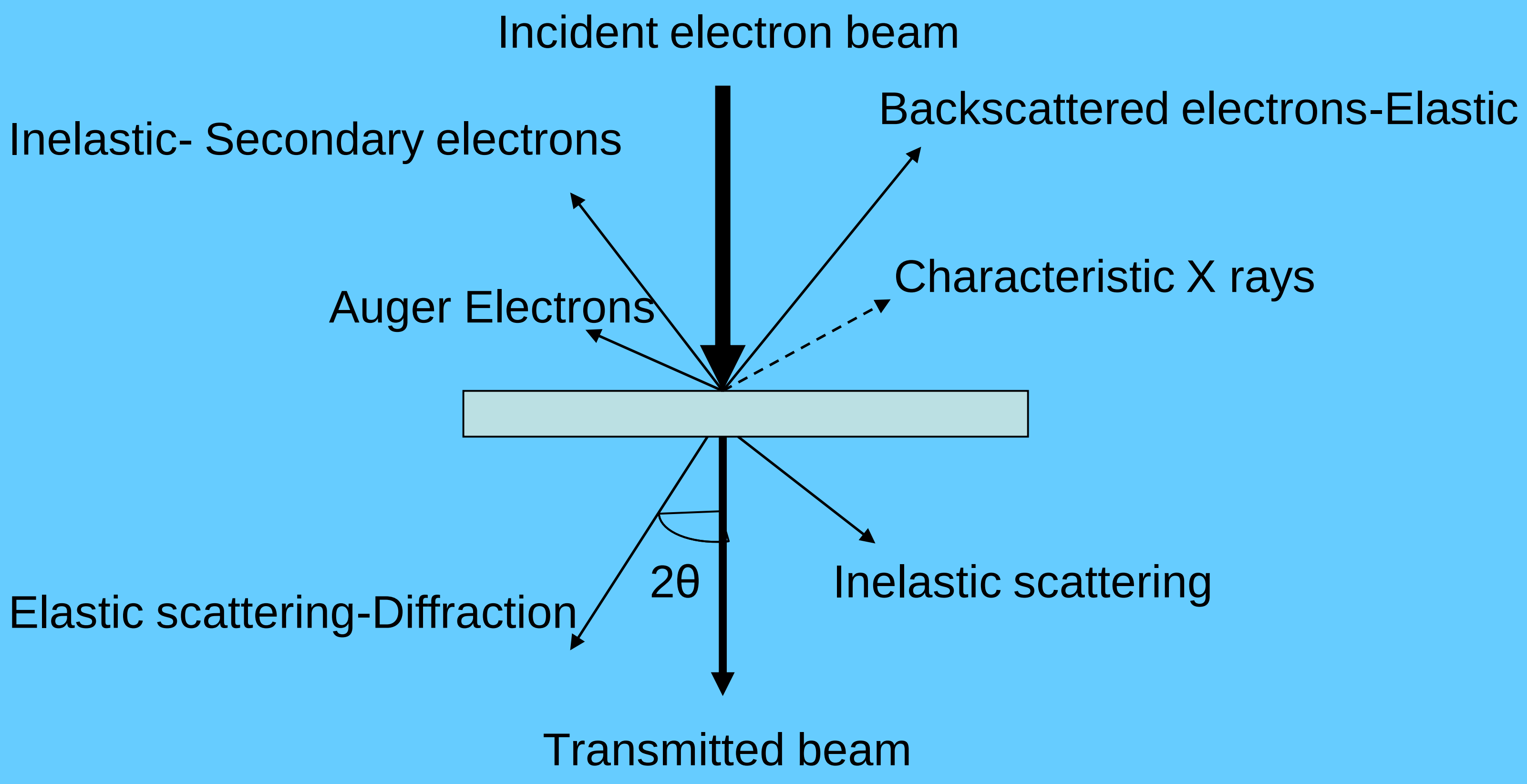
$v$ = velocity of the electron

U = Potential drop

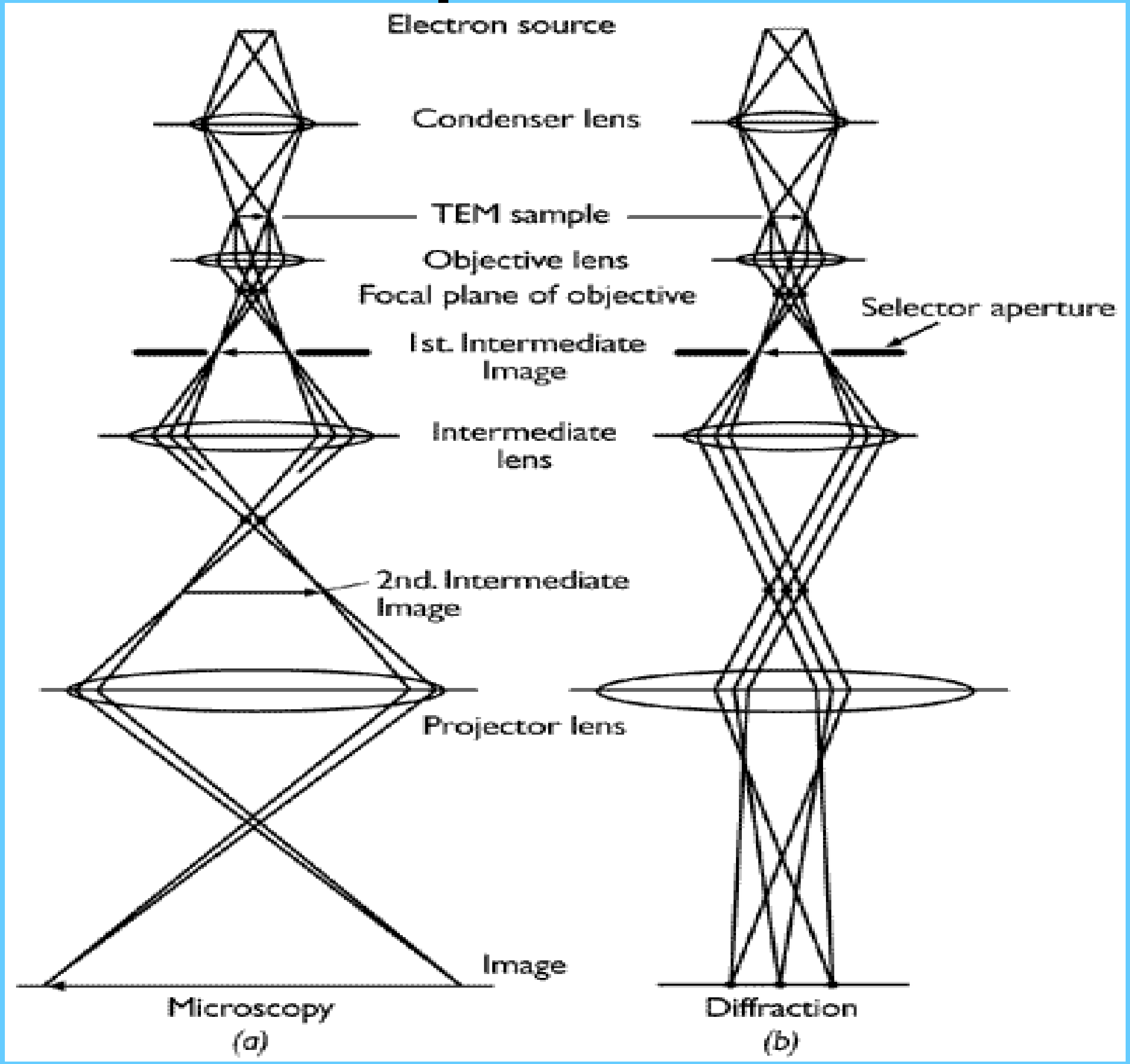
$\lambda = (1.23 \text{ nm}) / U^{1/2}$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_0 eU + \left(\frac{eU}{c}\right)^2}}$$

# Electron Sample Interaction



# Optics of the TEM



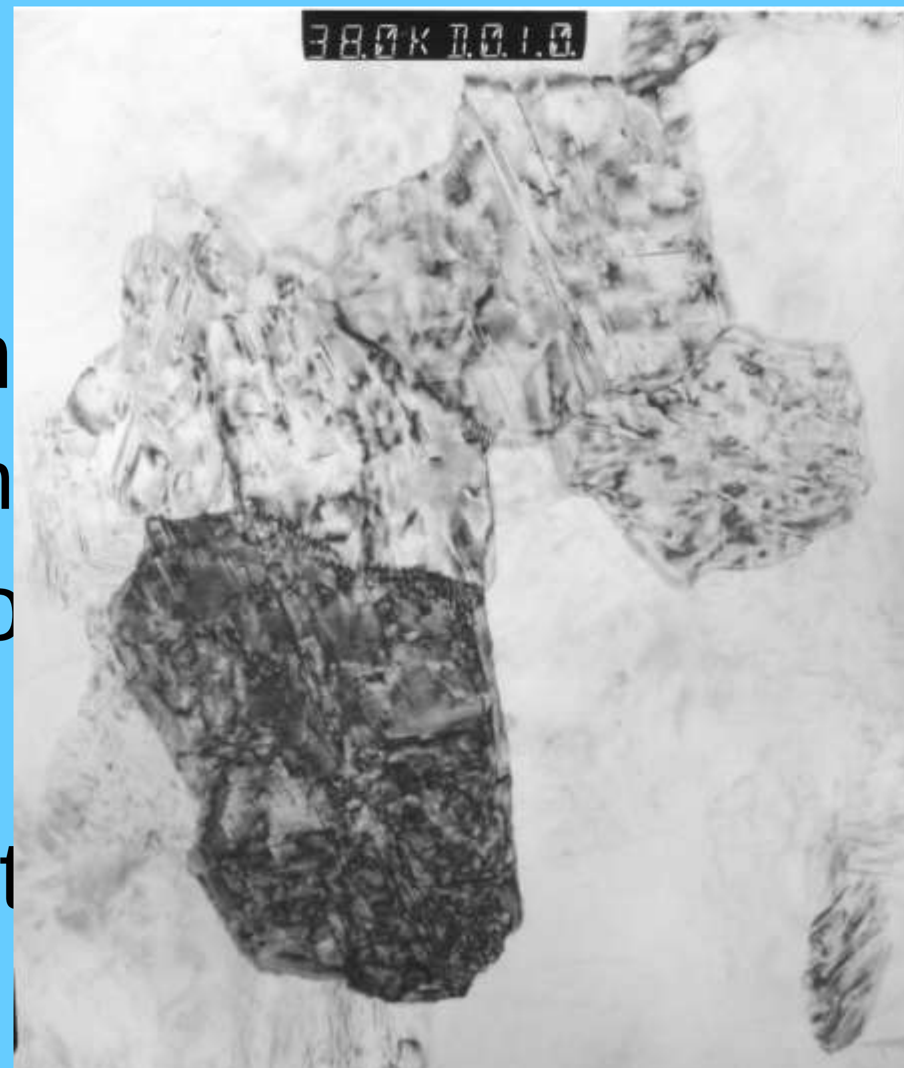

- Gun
- Lenses

    Focal length

- Apertures
- Screen

# Image Contrast in TEM

- Thickness
- Composition
  - Atomic num
- Diffraction (o
- Strain fields
- Fringe Effect



# Diffraction in TEM

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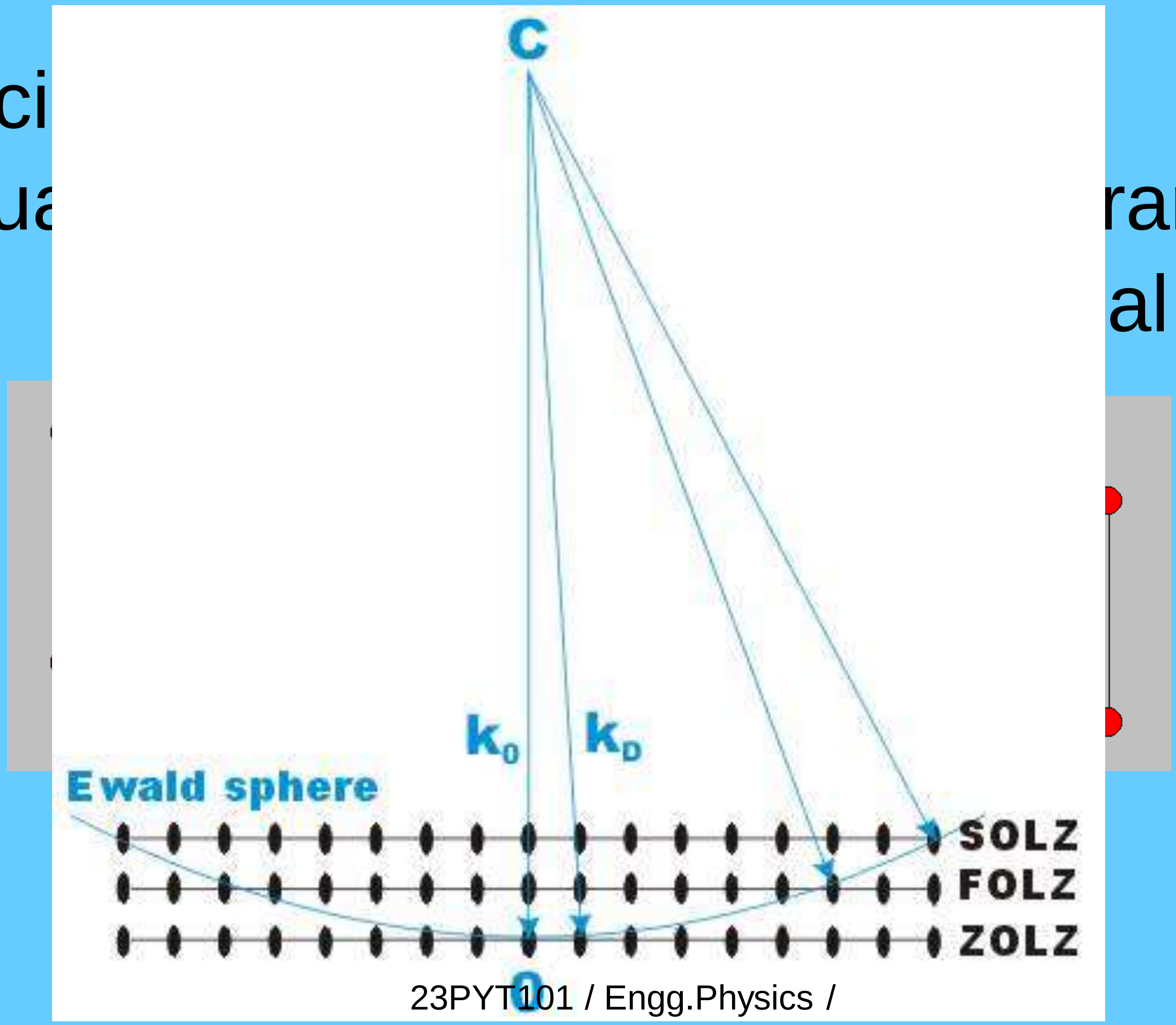
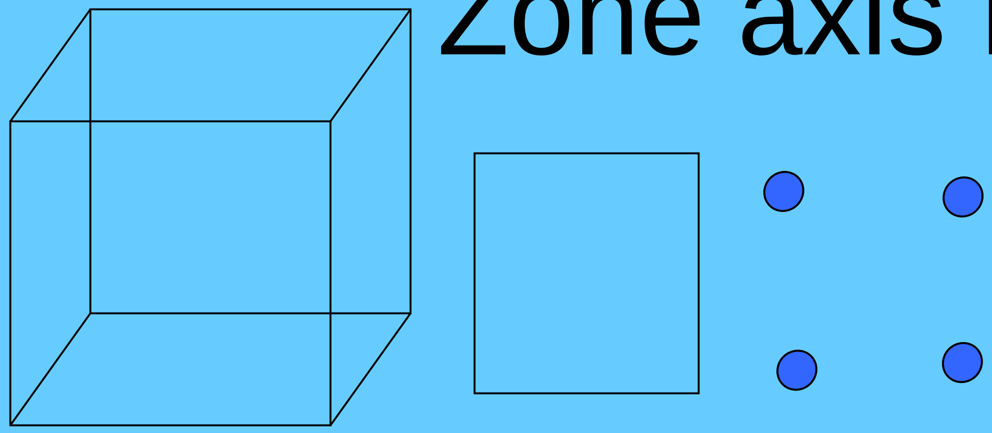


# Zone axis for SC



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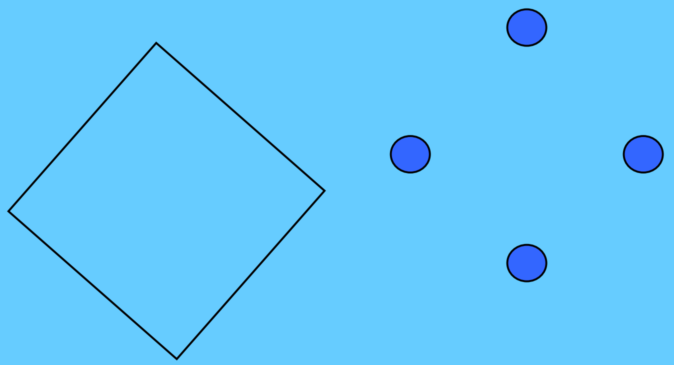

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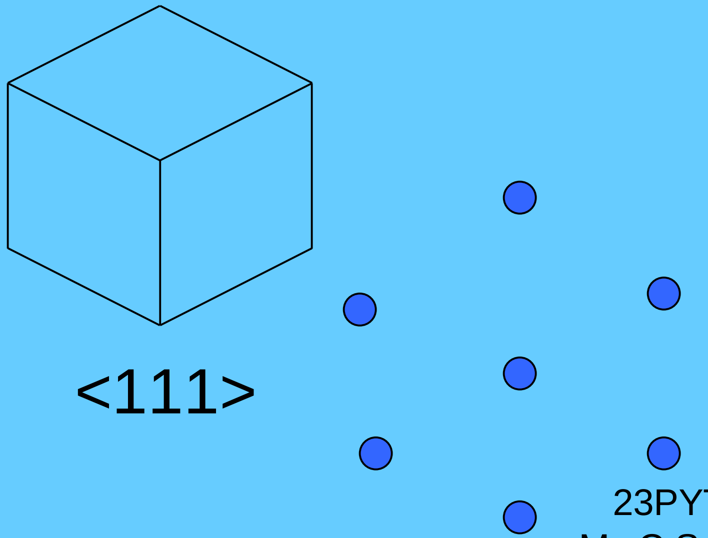

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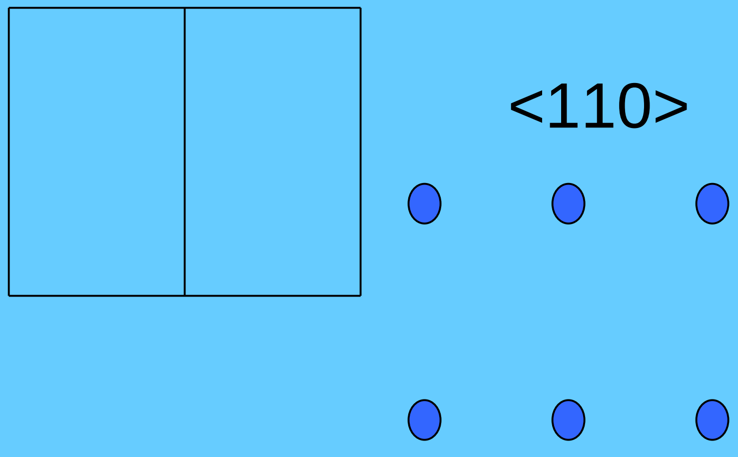

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# Real to Reciprocal lattice equations

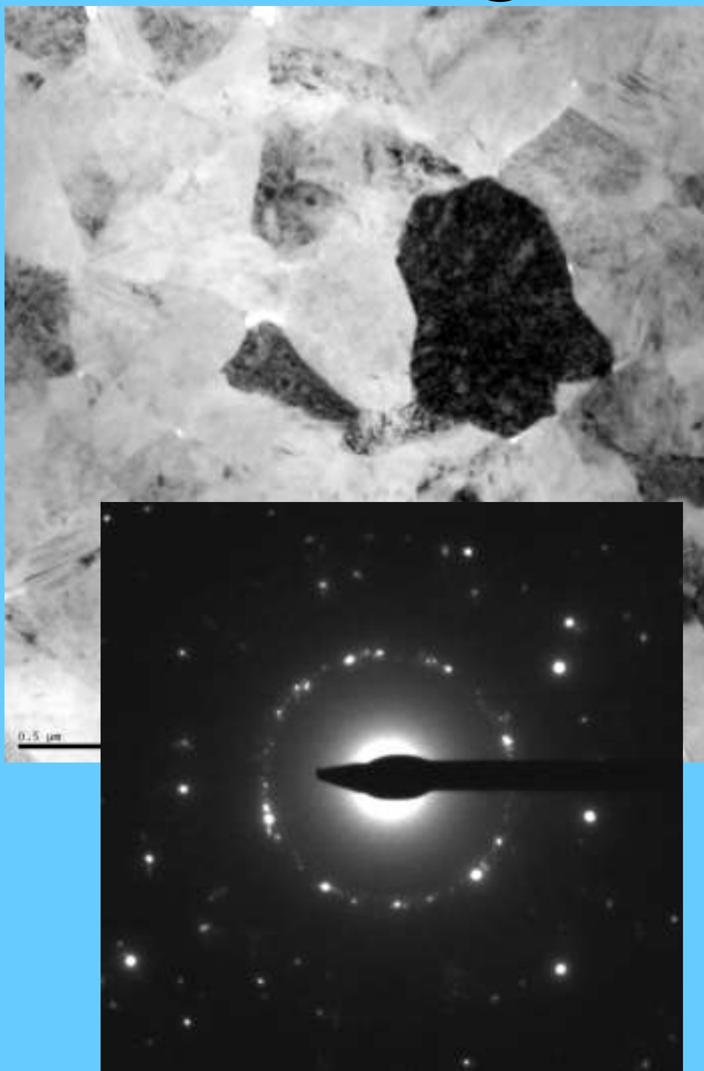
## The relationship

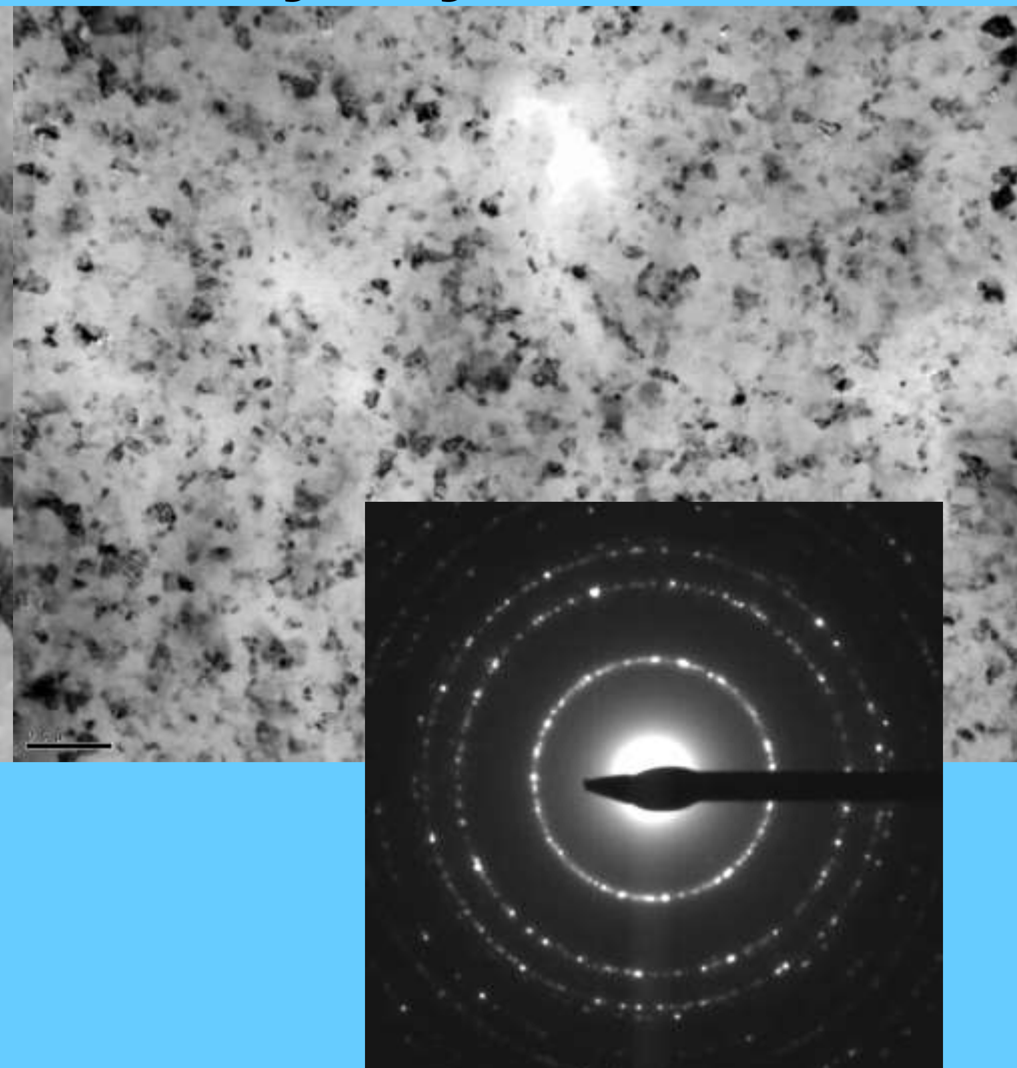
- Bragg's law $n\lambda = 2d \sin\theta$
- Laue equation $\boldsymbol{r} = (\boldsymbol{S}-\boldsymbol{S}^0) / \lambda$
- Fourier Transform $F(s) = \int_{-\infty}^{\infty} dx\, f(x) \exp(-i2\pi sx)$

## Structure factor

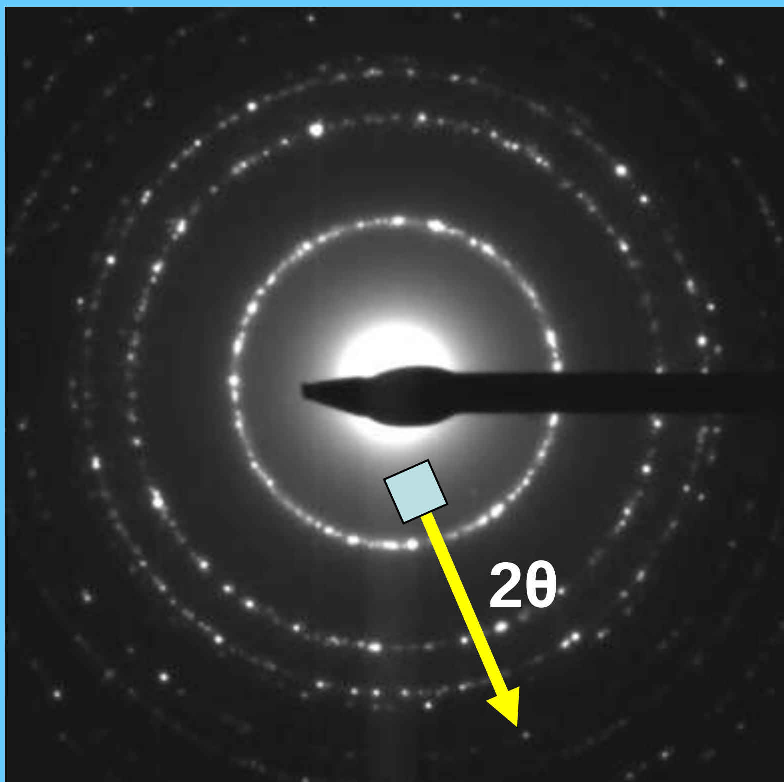
$$F_{hkl} = \sum f_n \exp \{ 2\pi i\, (hx_1 + ky_1 + lz_1)\}$$

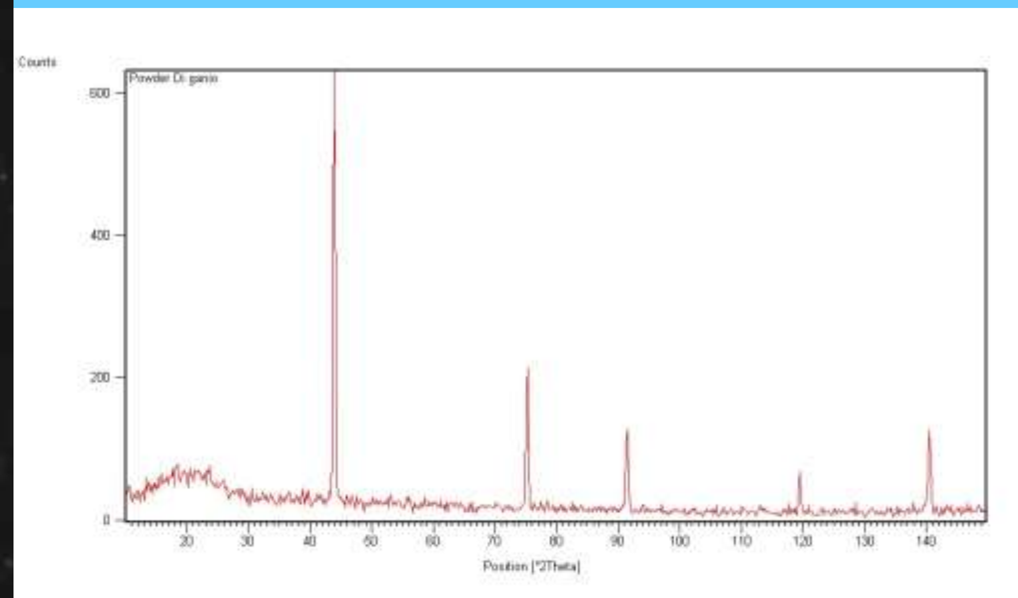
# Single vs Polycrystal





# Electron vs XRay Diffraction

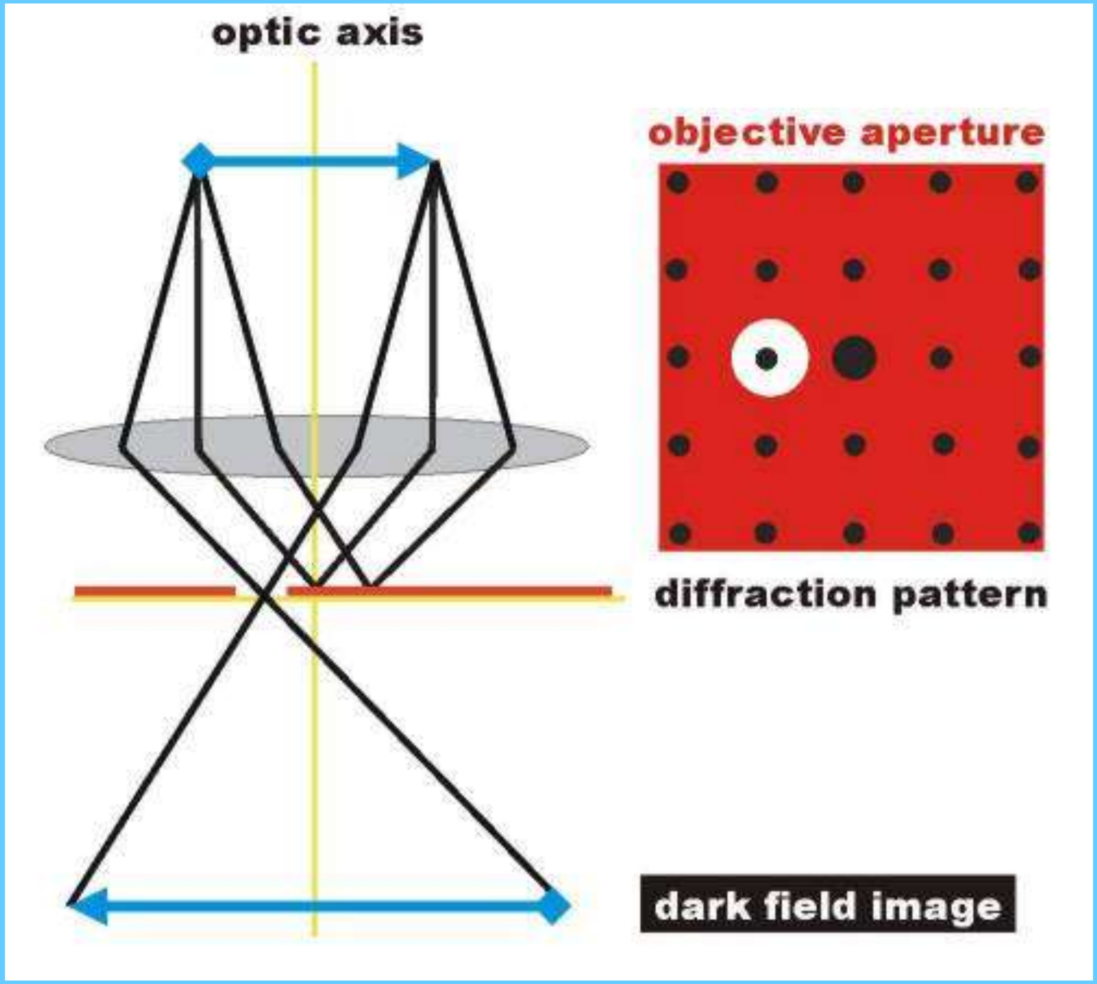


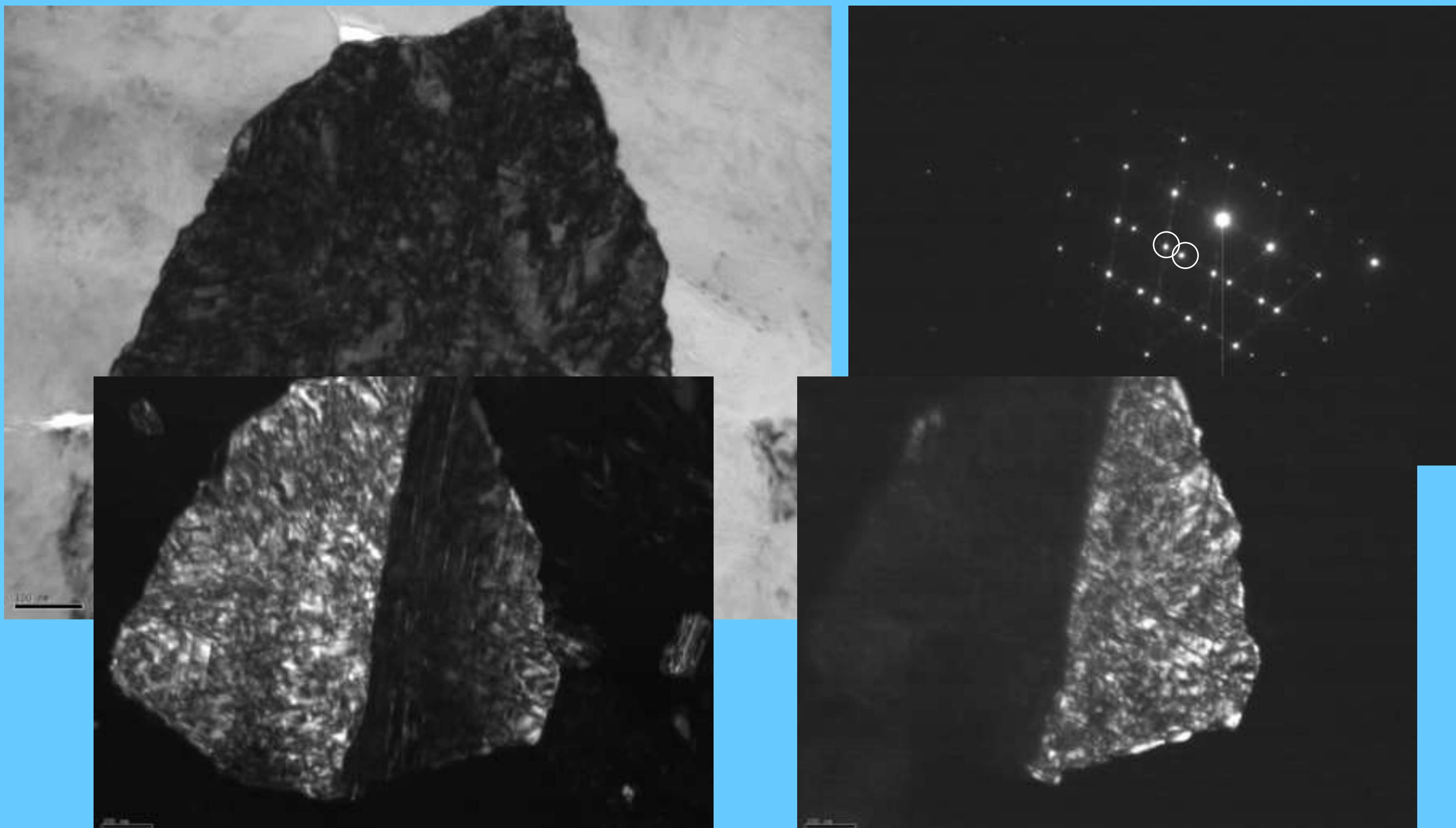
# TEM Diffraction- What can we infer?

- Phases and crystal structure types
- Crystal symmetry and space group
- Orientation relationships between phases
- Determining growth directions, interface coherency
- Identifying defects , i.e. twinning, SFs, Dislocations
- Ordering behavior of crystal structures and the site occupancy preferences

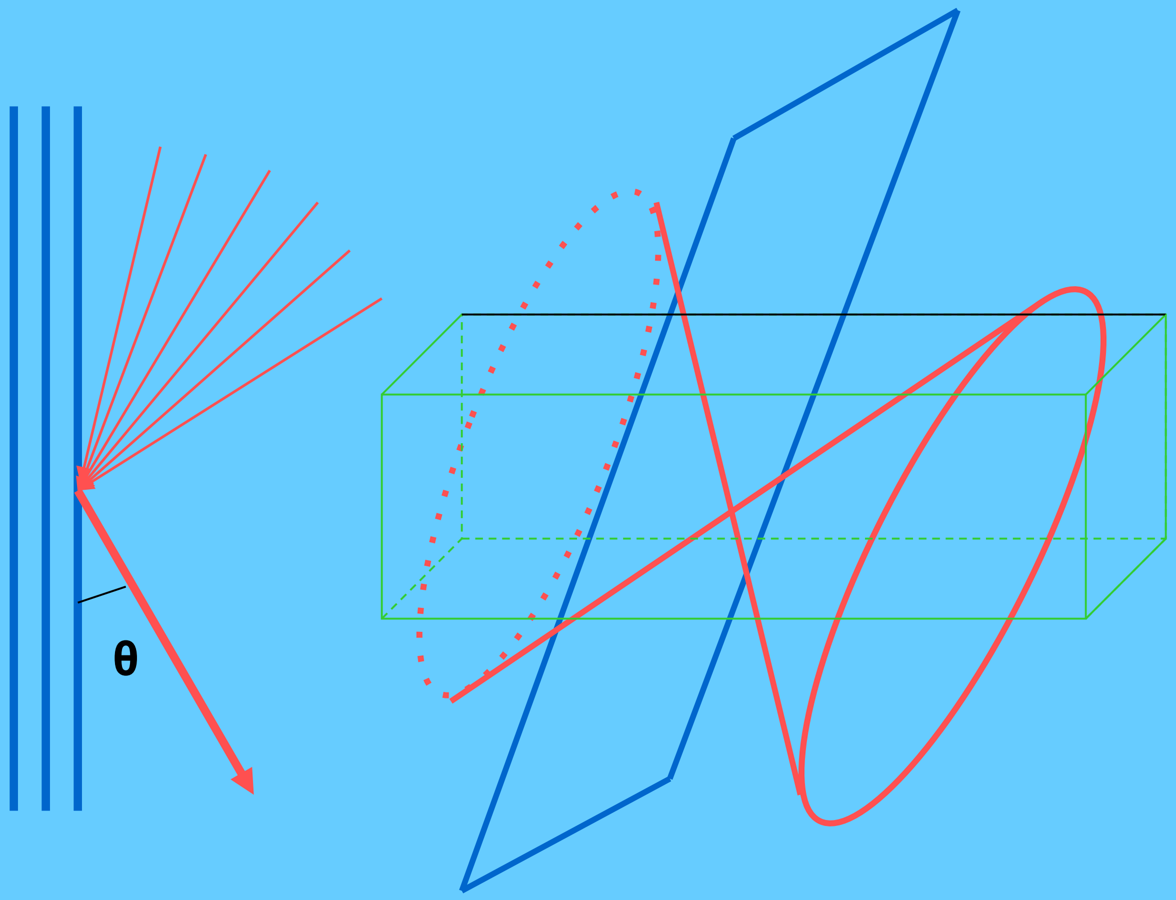
# Dark field imaging



# Dark field imaging

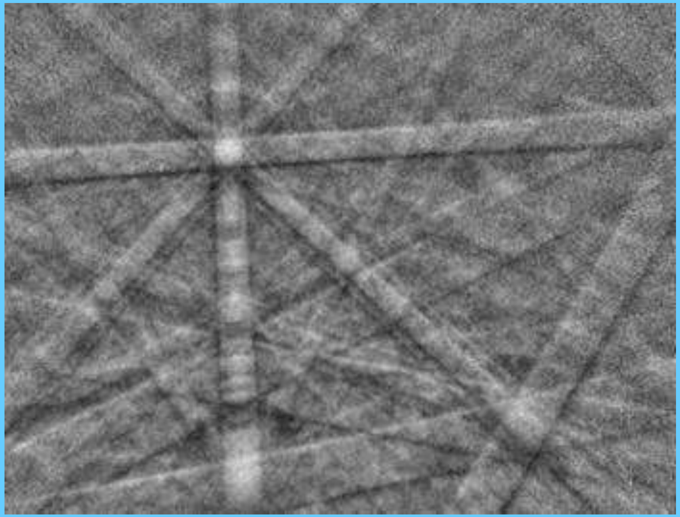


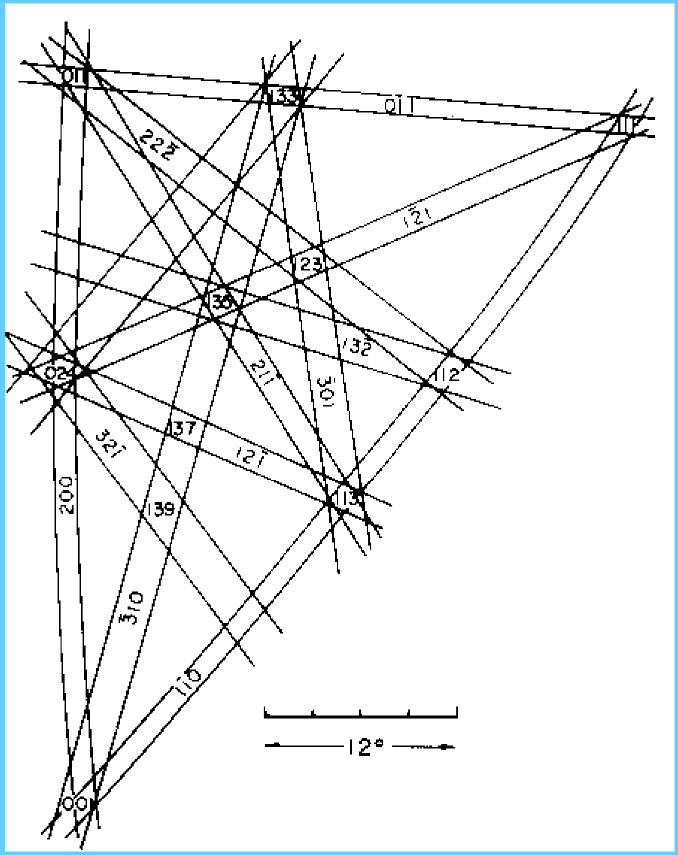
# Kikuchi lines



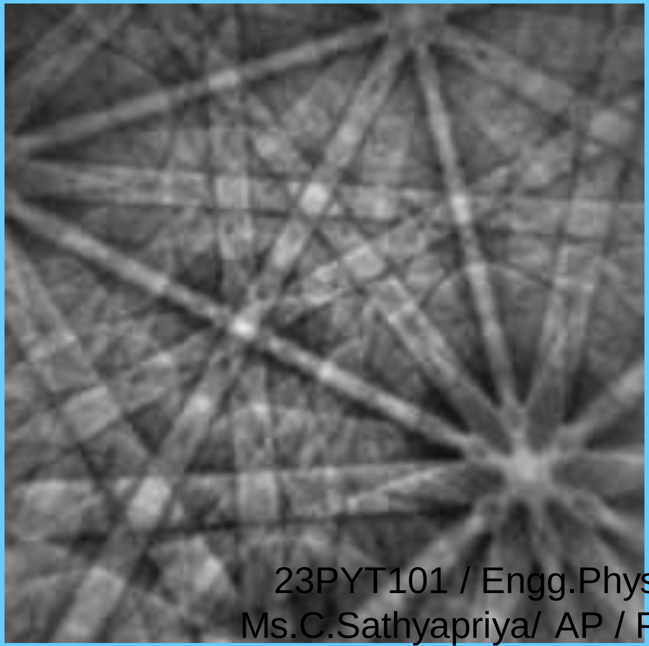

Inelastic scattering without significant wavelength change leads to formation of Kikuchi lines by diffraction. Incoming beam has every possible direction. Outgoing strong beam is at Bragg angle. This is particularly seen in thick samples

# Kikuchi Maps









# More….

- Transmission Electron Microscopy- Dr. Vasudevan's Graduate Course
- Transmission Electron Microscopy – David B. Williams and C. Barry Carter
- Transmission Electron Microscopy – Ludwig Reimer